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Climate Science Research Partnership

Improving predictions of climate variability and change in Africa

Photo: Andrew McConnell/Panos

"When I was a young man in this village, the rains used to start in March. Now the rains do not come until… May, and farmers have to prepare their lands and wait…"

Village leader in Ghana[1]

Since January 2010, the Climate Science Research Partnership (CSRP) has been working to improve predictions of climate variability and change in Africa. By taking a consultative approach, it is developing research products that respond to demand in Africa and are accessible to users. This brochure discusses why the CSRP is needed and describes some of its diverse activities.

Background

Climate variability and change have enormous impacts on many aspects of human development and well-being. Nowhere is this more the case than in Africa, where rain-fed agriculture is by far the most common form of cultivation. For the millions of people whose food security depends on there being enough rain to sustain crops, coping with variable rainfall is becoming more and more important.

Substantial and sustainable poverty reduction can be achieved in Africa through better predictions of climate variability and change. Improved forecasting would help farmers to schedule their seasonal activities, planners to design effective early warning systems and decision-makers to prioritise the most effective response and adaptation strategies.

More accurate prediction demands enhanced understanding and modelling of the African climate. But this alone is not enough. For new scientific advances in climate science to have an impact on poverty and food security, they must be based on the needs of African climate services and those who rely on their seasonal and long-range forecasts.

The CSRP is a partnership between the Met Office Hadley Centre and the UK Government's Department for International Development. It is carrying out several complementary streams of scientific research to investigate and model drivers of variability and change in the African climate. This research has been designed to respond to the findings of a systematic consultation with African stakeholders that identified priorities for improved prediction. The partnership also has a range of capacity development strategies to enhance the professional development of African climate scientists.

Through its consultation and collaboration with regional climate organisations and African National Meteorological and Hydrological Services (NMHSs), the CSRP responds to the need for much closer and sustained partnerships between producers and users of climate information. Such partnerships form an important part of the implementation planning for the Global Framework for Climate Services, an international initiative developing under the United Nations (UN) system.

1. Simelton, E. et al. 2011. *African farmers' perceptions of erratic rainfall*. Sustainability Research Institute Paper No. 27. School of Earth and Environment, University of Leeds. p.17.

Cover photo: Graeme Williams/Panos

Challenges and strategies

The majority of Africans are dependent on climate-sensitive sectors and activities for their livelihoods. This makes them particularly vulnerable to hazardous weather and climate variability. Widespread poverty and weak infrastructure also mean that there is little capacity to adapt to climate change.

These challenges are compounded by a lack of appropriate information for effective response and adaptation planning. So improving predictions of climate variability and change is critical to making progress in many development sectors, from food security to water availability to human health. But it is also important to be able to attribute the causes of extreme weather events that have already happened, because this can mean avoiding inappropriate and potentially expensive adaptation.

Why is there a shortage of applicable information about climate variability and change in Africa?

In 2007, the Fourth Assessment Report from the Intergovernmental Panel on Climate Change (IPCC)[2] showed that drivers of climate change in Africa were poorly understood, and that climate models were not providing a consistent picture of future changes in rainfall across Africa. The assessment prioritised not only research on the drivers of African climate change, but also better representation of these key processes in the current generation of climate models.

Improved understanding is clearly essential. But for information about the future climate in Africa to be useful to decision-makers and planners, it is needed at regional, national and even sub-national scales. This demands the scaling down of global climate information to the local level.

A better supply of applicable information would be a big step in the right direction, but attention must also be paid to the way this information is used. In previous climate negotiations, developed countries have repeatedly committed themselves to narrowing the significant capacity gap that exists in African climate science, and this work continues to be essential. African climate scientists are a key link in the chain of evidence-based decision-making and planning that is needed for successful adaptation to climate change.

''Improved predictions of climate variability are particularly important for Kenya because agriculture contributes about 22% of gross domestic product (GDP) and employs more than 50% of the population. More than 60% of energy generation is hydroelectric and hence heavily dependent on rainfall. Kenya is particularly susceptible to marked inter-annual variability in rainfall totals that give rise to damaging drought and floods. Climatic extremes have in the past reversed economic growth.''

Mrs Mary Kilavi, Kenya Meteorological Department and CSRP Fellow

2. IPCC. 2007. *Fourth Assessment Report: Climate Change 2007*. IPCC, Geneva, Switzerland

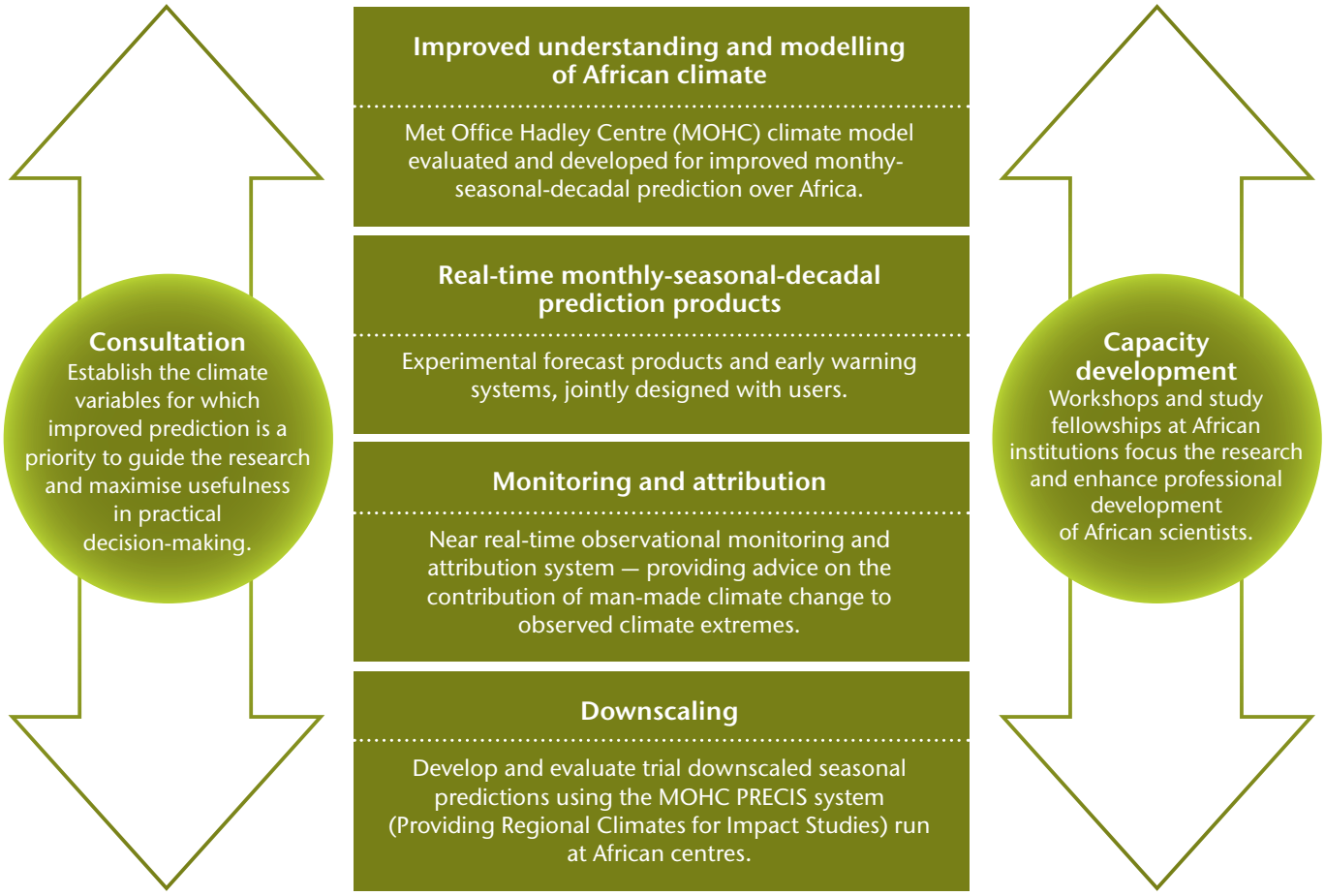
The CSRP is working to meet these diverse challenges by:

- improving understanding of the drivers of African climate variability and change;
- working with African regional climate organisations and NMHSs to create new, much-needed forecast products;
- developing systems for climate monitoring and attribution of extreme weather events;
- supporting the development and use of climate science in Africa.

It is carrying out these essential activities through:

- consultation with African stakeholders to establish the priorities for improved prediction;
- research on understanding and modelling the African climate and drivers of climate variability and change;
- capacity development activities, including a Fellowship programme, to support the professional development of African scientists.

CSRP – Africa



How do existing models need to improve over Africa?

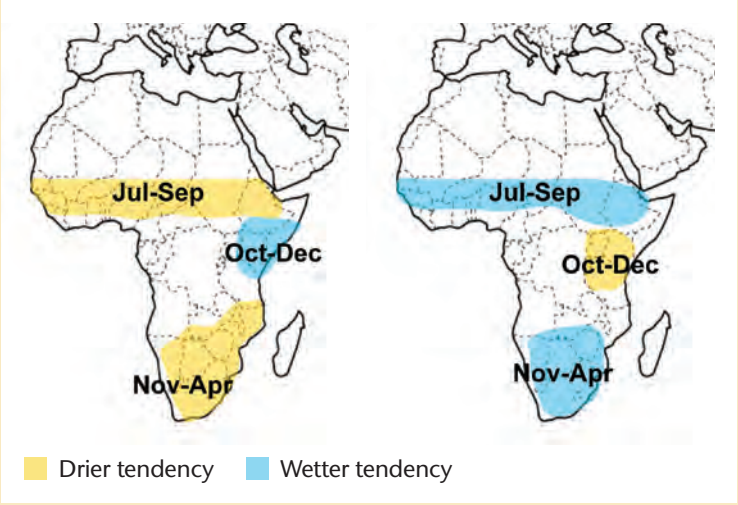
At the earliest stage of the CSRP, scientists began testing existing global climate prediction models to see how well they perform for Africa.

The tests identified some areas where significant improvements were needed. For example, some well-known influences of global sea-surface temperature on African rainfall — so-called 'teleconnections' (see below) — were not adequately reproduced in the long-term climate simulations produced by existing models. Testing has pointed the way to improving these models, in turn helping to improve climate predictions.

TELECONNECTION LINKS

'Teleconnection' describes two sustained climate events which are related to each other across very large distances. Teleconnection links that have particular relevance for the African climate are those associated with El Niño and La Niña events when sea surface temperatures in the tropical Pacific Ocean are above (El Niño) or below (La Niña) normal.

Regional rainfall tendancies in Africa during El Niño (left) and La Niña (right)



CSRP scientists gathered observation data on teleconnection links and compared them with predictions generated by the Met Office Hadley Centre's HadGEM3 climate model, to assess the model's performance. This comparison was part of a comprehensive assessment of the ability of current models to represent teleconnection links. It was found that most state-of-the-art ocean-atmosphere models do not represent some important teleconnections well enough in long-term simulations of climate. CSRP research has brought this to the attention of the climate science community and is pointing the way for improved modelling — leading to better forecasts.

CSRP FELLOWSHIP RESEARCH: EXPLORING TELECONNECTION MECHANISMS

CSRP Fellow Wilfried Pokam Mba is currently based at the Centre for International Forestry Research in Yaoundé, Cameroon, on secondment from his home institute, the University of Yaoundé. He is a climate research scientist specialising in the study of atmospheric thermodynamics, and his current interest is in identifying the key processes driving climate variability in central Africa. His CSRP Fellowship research is examining the low-level westerly winds from the Atlantic Ocean which drive the flow of low-level moisture during the September to November rainy season. He says that "very little is known about the processes which control the height of these low-level westerlies, the seasonal and interannual variability of their strength, or how they are maintained throughout the year".

As part of this study, Mr Pokam Mba will be exploring the teleconnection mechanisms between low-level moisture flow and the Saint Helena anti-cyclone, the Benguela current, the low-level jet along the Namibian coast and El Niño events.

Testing also revealed that some key African climate systems — for example, the West African Monsoon (WAM), West Africa's primary rain-bringing system — were not well represented in most climate models. Improved understanding and modelling of such systems is urgently needed to bring about a better physical basis for prediction.

One model that was found to have a good representation of the WAM was the Met Office Hadley Centre's HadGEM3. The model's simulation of the WAM is realistic enough for it to be used as a virtual laboratory to study monsoon processes.

This is helping to increase understanding of the factors which influence the timing of monsoon onset, an event of huge importance to farmers.

Research on teleconnection links and other tests of model performance are crucial to improve large-scale climate models. They advance the scientific physical basis of the models, which underpins reduced uncertainty in predictions of African climate variability and change.

What climate information do African decision-makers need?

At the heart of the CSRP's research activities is a commitment to provide information that is useful for practical decision-making.

So, one of the first priorities in the CSRP's work was to consult African stakeholders. The aim was to discover how research could best enhance the range and quality of information available to them.

More than fifty interviews were held with a range of respondents in eight African countries. They represented regional climate organisations, national meteorological and hydrological services, universities, non-governmental organisations, government ministries and organisations using climate information to provide support to vulnerable communities. The interview questions were targeted at finding out how existing climate prediction data could best be developed or extended. Respondents were also asked about their training needs.

The key results of the interviews were that:

- the need to improve understanding and modelling of the African climate is urgent;
- the highest priority is to develop capability to predict the seasonal onset and duration of rainfall and the frequency of dry spells;
- improvements in predictions up to six months ahead are higher priority than longer-term predictions, but ten-year predictions (multi-annual to decadal) are also urgently needed for adaptation planning.

As well as these interviews, nine African climate services responded to a technical questionnaire. They were given a series of research priorities and asked to rank them in order of importance. The results echo those of the interviews, with the majority of respondents ranking the development of forecasts of the temporal distribution of rainfall – for example, when seasonal rains will start and end – as their top priority for research. Developing models with greater geographical detail (spatial downscaling) and improving understanding of extreme rainfall events are also seen as important.

The outcomes of the consultations have shaped the science and training components of the CSRP, ensuring that they reflect the views and priorities of stakeholders in African climate science.

Ranking of research prioritised by African climate services

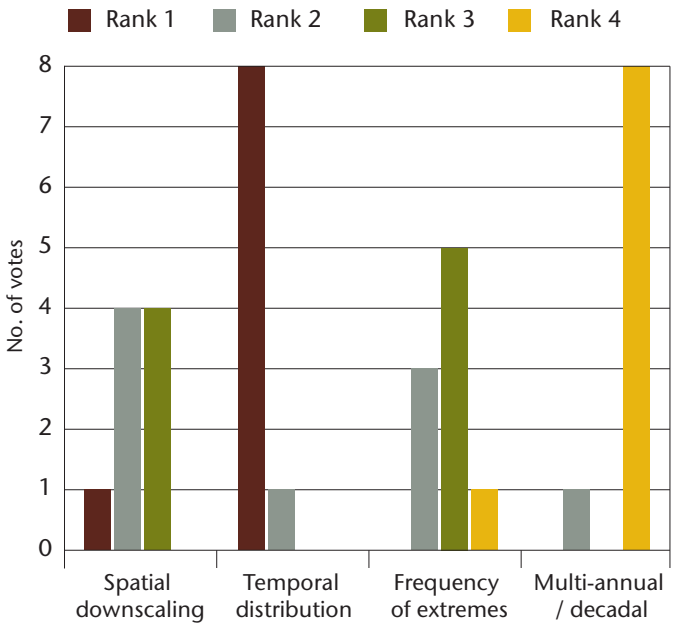


Photo: Richard Graham, Met Office

Workshop participants at the CSRP climate science workshop on a field trip to observe climate change and land use impacts in the Masaii rangelands near Nairobi, Kenya.

New seasonal rainfall prediction and monitoring tools

Reliable forecasts of seasonal rainfall are crucial for agriculture and food security. At present, most seasonal rainfall forecasts offered by African meteorological services are based on statistical models. These produce predictions based on connections between different aspects of the climate, such as year-to-year fluctuations in sea-surface temperature and seasonal rainfall. Such connections are derived by analysing past data, typically for the last 20-30 years.

But with the advent of climate change, the past is becoming less reliable as a guide to the future, and we must look to dynamical methods of prediction that are based on climate models. Unlike statistical models, dynamical seasonal forecasting systems like the Met Office's GloSea4 system work by replicating the actual physical processes in the climate system and take account of the influences of climate change. To strengthen the basis of forecasts, CSRP has been working with African scientists to develop ways of using dynamical models alongside statistical methods in the preparation of seasonal forecasts for the continent.

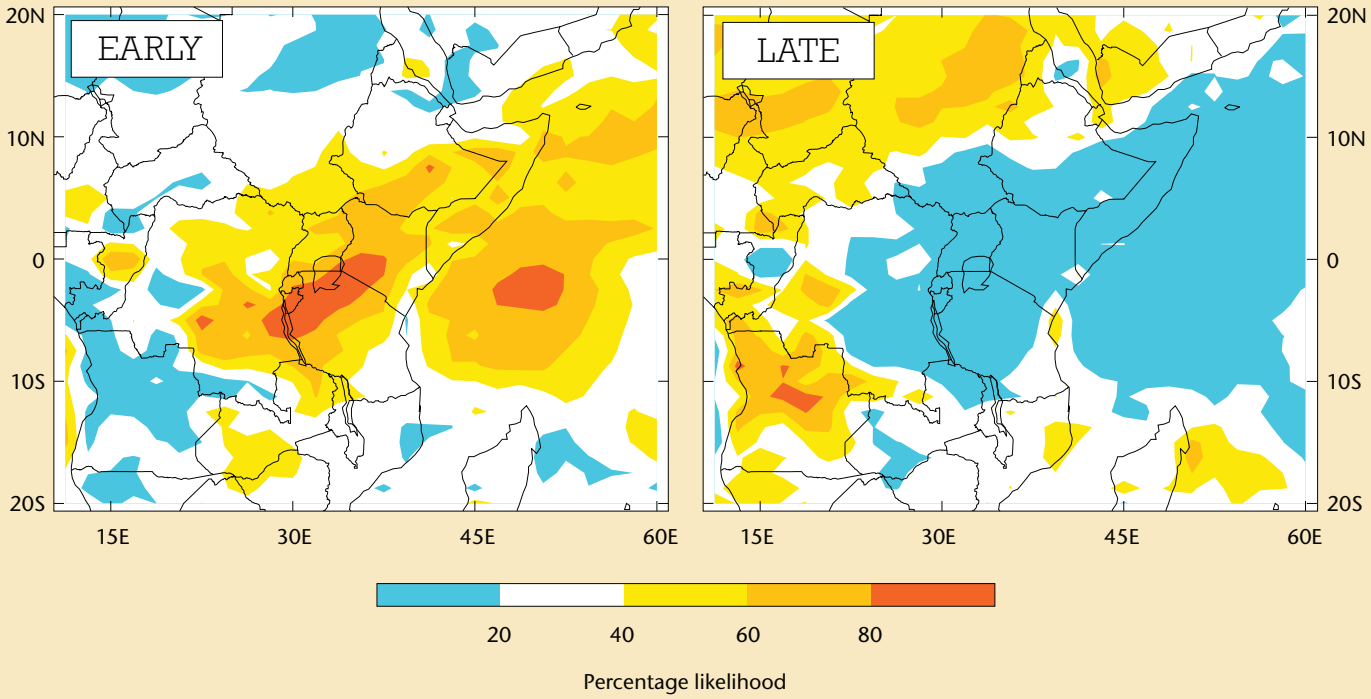
As well as forecasts of the total amount of seasonal rainfall, forecasts for when the rains will start are also important for crop-planting decisions: if crops are planted too early, seeds will rot in the ground; if planted too late, the harvest may not have time to ripen.

Participants at the CSRP Climate Science Workshop, with colleagues at ICPAC, produced the first ever consensus rainfall prediction for the July to September rainy season, which is particularly important for livelihoods in the northern part of the Greater Horn of Africa.

In the early stages of the CSRP, researchers at the Met Office Hadley Centre used the GloSea4 system as the basis for developing and evaluating experimental forecasts of the timing of rainfall onset for different regions in Africa. This formed a strong foundation for engaging with African climate scientists to develop optimum ways of integrating data from dynamical models into their seasonal rainfall forecasts.

The experimental forecasts are undergoing trials at three Regional Climate Outlook Forums in West, East and Southern Africa. Here, experts from the region and from international prediction centres meet with users to review the recent climate and its impacts, to prepare a forecast for the coming season and to discuss appropriate responses to it.

Probability forecast for onset of short-rains season, Greater Horn of Africa, 2011



EXPERIMENTAL FORECASTING OF RAINFALL ONSET

Experimental forecasts of rainfall onset timing have been developed using the Met Office's climate model-based seasonal forecasting system, GloSea4. The forecasts calculate the probability that the onset of the rainy season will be earlier or later than normal. From the definitions of 'early' and 'late' used in the research, both normally have an expected 33% probability of occurring.

The figures show an example forecast, issued in August 2011, for that year's October – December short-rains season over the Greater Horn of Africa (GHA). The orange and red shading in the left-hand figure shows that the predicted probability of early onset was greater than 60% over the GHA — much higher than the normal odds (33%). The predicted probability of early onset was also much higher than the predicted probability of late onset, which was less than 20% in the region, as shown by the blue shading in the right-hand figure.

The onset of the rains was indeed early over much of the area where this was predicted with high probability.

This single case is not enough to evaluate the performance of the forecasting method. But assessment of 14 years of retrospective forecasts over Kenya and Tanzania is very encouraging, with early or late onset being correctly identified in about 70% of cases. This shows that dynamical seasonal forecast systems can work well to predict variability in the onset of Africa's rainy seasons.

Valuable lessons learned in developing these forecasts have contributed to the design of materials for climate science training. These were put into action during the first CSRP Climate Science Workshop, 'Appreciation and Use of Dynamical Seasonal Forecasts for the Greater Horn of Africa', hosted in collaboration with the Intergovernmental Authority on Development (IGAD) Climate Prediction and Applications Centre (ICPAC) in Nairobi.

Held in June 2011, the two-week workshop gathered 15 scientists from the national meteorological services of East Africa. While it aimed to take stock of the current seasonal forecasting methods used by countries in the region, the workshop's primary emphasis was on strengthening the understanding of dynamical models and their use in forecasting. Most of the sessions were hands-on interactive exercises designed to give participants maximum exposure to the principles and techniques of dynamical seasonal forecasting. Additional skills acquired at the workshop helped participants to collectively develop, with ICPAC, the first ever consensus prediction for the July to September rainy season in the region. This forecast was shared with users of climate products at a forum at the end of the workshop.

In addition, rainfall monitoring is important for climate preparedness, particularly for early warning of drought. The CSRP has developed experimental rainfall monitoring information, such as the observed date of the onset of the rains and the length of the latest dry spell, and trialled them with users in Africa.

Photo: Stuart Freedman/Panos

''Most studies that have assessed the impacts of climate change in Africa have used large-scale global climate models which provide very little information that is of practical use to decision-makers on the precise extent and impacts of climate change, especially for any specific location within a country in Africa.''

The Impacts of Climate Change in Africa, 2006[3]

Making predictions at the right scale

The seasonal outlooks issued by regional and national meteorological centres in Africa increasingly make use of information from global climate models. Models at this scale are essential for capturing patterns and interactions of the global climate, like teleconnection links and the influence of El Niño on regional rainfall. But they do not provide the detailed regional predictions that decision-makers want.

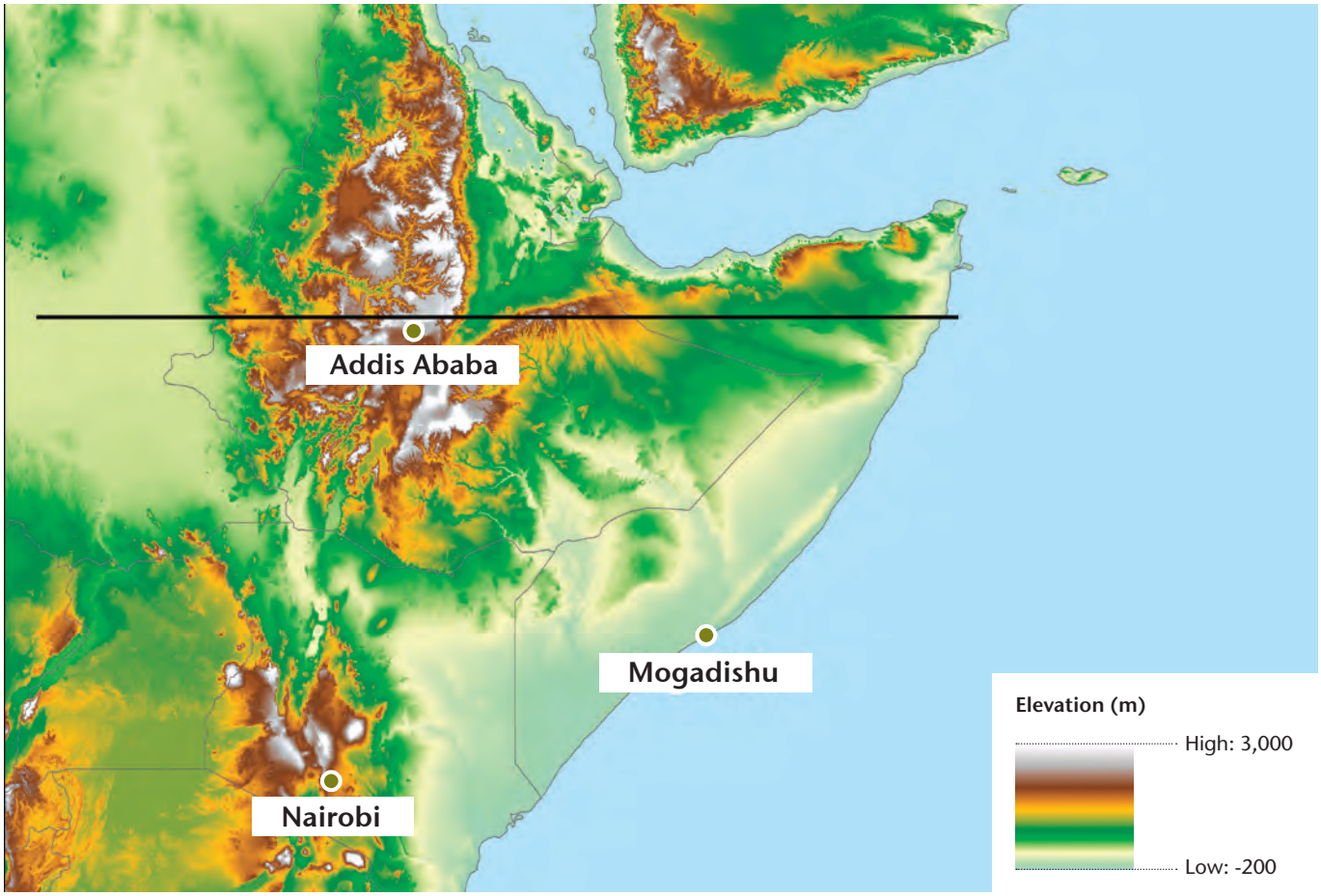
Regional climate models focus on a specific region rather than the whole globe. They contain more details of regional topography — like mountains and deserts — which influence variations in local climate, and are better at simulating weather events like storms and extreme rainfall. This means that when they are 'fed' with information from global models, they are able to provide greater geographical and temporal detail in forecasts.

The CSRP is working on the coupling of global and regional climate models so that the regional model adds a 'magnifying lens' to seasonal forecasts made by the global model — a process known as 'downscaling'. A new regional climate model based on HadGEM3, developed at the Met Office Hadley Centre, has been installed at ICPAC in Nairobi. This innovative collaboration is exploring strategies for the future use of downscaled forecasts for rainfall prediction in Africa.

The new regional model was used to build training material for the second CSRP Climate Science Workshop, which examined the benefits and challenges of using downscaled information to help generate seasonal forecasts for the Greater Horn of Africa. It is also being used for climate change studies beyond as well as within Africa. CSRP scientists are working with the World Climate Research Programme's Coordinated Regional Downscaling Experiment (CORDEX) initiative in its initial focus on Africa, and the Met Office Hadley Centre is providing CORDEX with simulations for all other land regions.

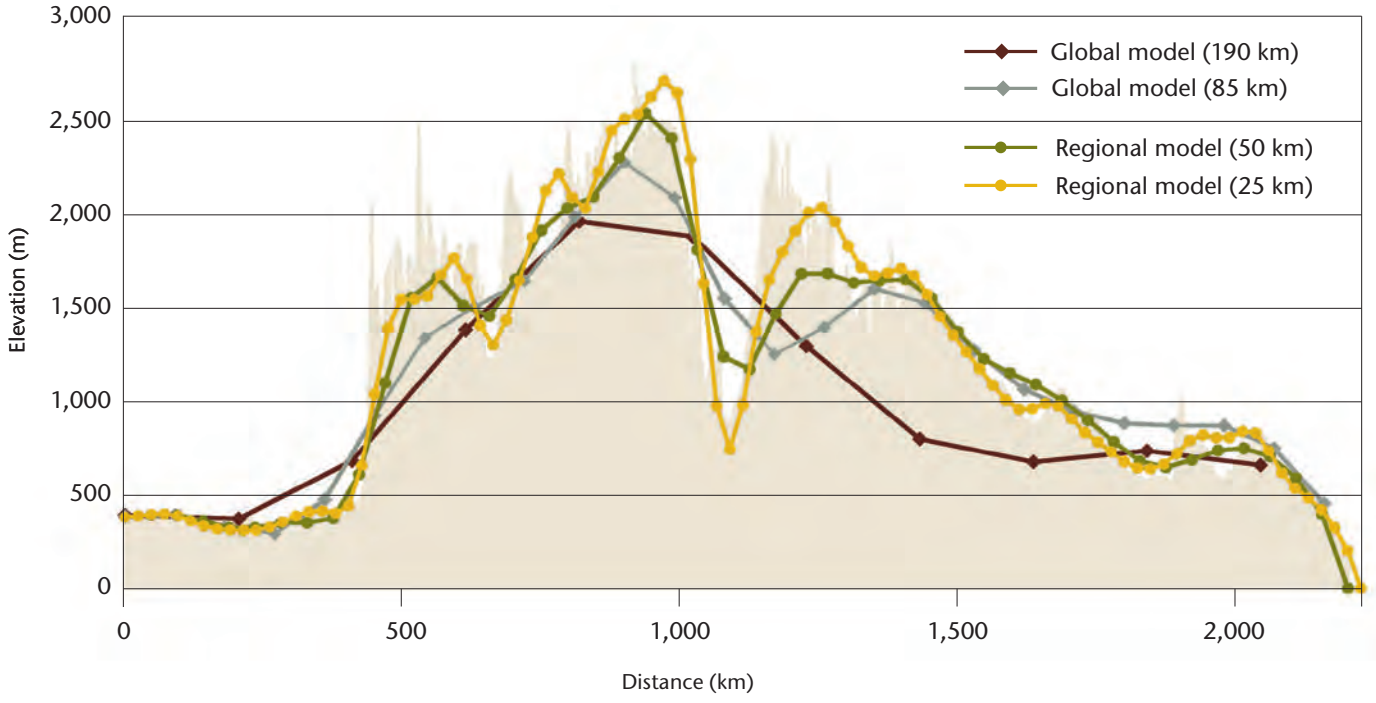
The new regional model will also form the core of the next version of the Met Office's regional climate modelling system PRECIS (Providing Regional Climates for Impact Studies). This was developed to help generate high-resolution climate change information for any region of the world. Mirroring the collaborative approach of the CSRP, PRECIS has been made freely available to scientists in developing countries so that they can create climate change scenarios at national centres of excellence, simultaneously building capacity and drawing on local climatological expertise.

3. Nkomo, J., Nyong, A.O and Kulindwa, K. 2006. *The Impacts of Climate Change in Africa*. Background paper for the Stern Review on the Economics of Climate Change. p. 2.

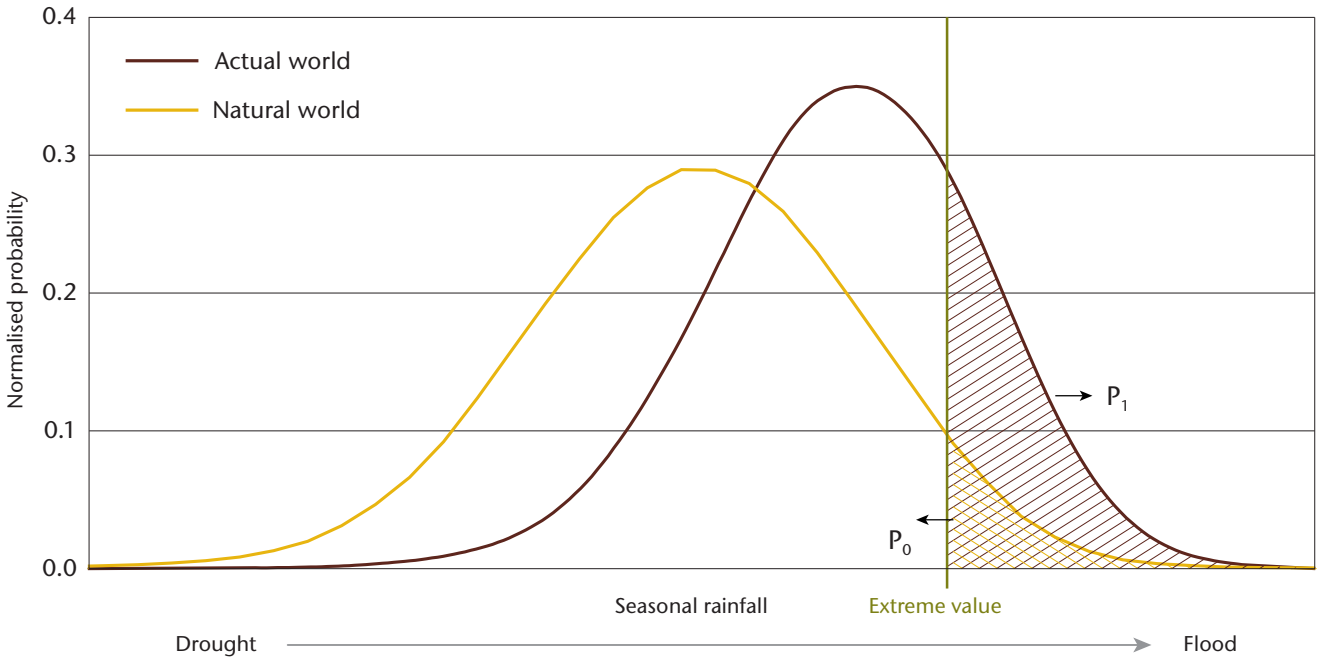


Representing the complex terrain of the Greater Horn of Africa in climate models

The realism of terrain in climate models depends on the spacing of 'grid points' used to represent meteorological processes. The cross section (below) through Addis Ababa shows how the 25 km spacing of the regional climate model used in CSRP downscaling work gives a more realistic description of terrain compared to other models with wider grid point spacing. This is important because complex terrain can drive important local climate variations.



Climate change and changing risk of extremes



Schematic illustrating the technique of event attribution, which determines how natural and/or man-made factors influence the probability of extreme climate events. The brown curve represents the current distribution of possible rainfall for a given region in the world following changes in the climate. The yellow curve represents the same, but for a world without man-made climate change. The vertical line denotes a value of rainfall, beyond which events are considered extreme. By comparing the area under the curves beyond this line (i.e. comparing P_1 to P_0), we can determine how climate change alters the probability of an extreme event. In this illustration floods become more likely, but distribution shifts of both directions are expected, depending on the region. Using climate models, CSRP research has generated realistic simulations of the curves shown in this example to assess the role of climate change in the severe drought over the GHA in 2010/11.

Looking forward: beyond the next rainy season

While farmers need information about when the next rainy season will start, adaptation planners need predictions over a much longer time range. But the science of decadal prediction, which mainly looks up to ten years ahead, is still very new.

The CSRP has been working on a new version of the Decadal Prediction System (DePreSys), based on HadGEM3. Working at the decadal timescale means that both natural variability and human-induced climate change must be taken into account. DePreSys starts from the observed state of the atmosphere and oceans, which is necessary to predict natural variations, but also includes the greenhouse gas and aerosol concentrations necessary to predict human-induced change.

The system has been particularly successful at predicting the cycles of sea-surface temperature fluctuations in the tropical Pacific — associated with El Niño and La Niña — which are key drivers of variability in African rainfall. Predictions up to 18 months ahead show significant agreement with observed patterns. This offers the potential for much longer lead-time on rainfall predictions than are currently available, buying time to prepare responses to potential drought or flood.

Decadal predictions have also improved capacity in the more challenging area of predicting rainfall and temperature averages over the next five to ten years. This research is helping provide valuable insight into medium-term climate trends and is essential to the development of resilience to climate change.

Looking back: explaining droughts and floods

As well as predicting future climate patterns, dynamic models like HadGEM3 can be used to analyse climate events that have already happened. This is particularly useful after extreme climate events like droughts or floods, when the question 'to what extent did human-induced climate change play a role?' is often asked. Finding an accurate answer to this question can mean avoiding costly errors in the design of adaptation strategies.

CSRP researchers have examined the global climatic factors that led to the severe drought of 2010–11, when the short and long rains both failed in the Greater Horn of Africa. HadGEM3 was used to contrast the rainfall response to the real climatic conditions that prevailed during the drought with a set of conditions simulated to represent a world free from the effects of human influence. This exercise showed that the drought was consistent with natural variability in rainfall patterns, and suggested that the failure of the 2010 short rains had little to do with human-induced climate change. But for the long rains this may not be the case, and analysis is ongoing.

Strengthening climate science in Africa

Strengthening African climate science is a powerful motivation for the CSRP. It is a thread that has run continuously through the diverse research activities of the partnership, marking it out as a valuable experience of collegiality and mutual support.

CSRP support for the development of African climate science focuses on both individual and institutional capacity, and is interwoven with the complementary strategy of bringing CSRP research into practical use. Activities in these areas include the following.

- Two major Climate Science Workshops held in collaboration with African regional climate centres.
- A Fellowship programme under which 11 CSRP Fellows from all the major regions of sub-Saharan Africa are carrying out research on a cross-section of CSRP themes. The Fellows are all climate researchers, scientists and practitioners. Each has a mentor at the Met Office Hadley Centre, and the opportunity to use CSRP research outputs in their own study.
- Participation in Regional Climate Outlook Forums (RCOFs) in East, West and Southern Africa. RCOFs are key activities, held in advance of the rainy season, that generate and disseminate seasonal forecast information across their region and develop the capacity of national climate scientists. The CSRP provides these forums with experimental forecasts and works with regional climate scientists to develop them, as well as assisting in the interpretation and use of dynamic seasonal forecasts in preparation of consensus forecasts for the region.
- Sharing results of CSRP research and capacity-building activities in a number of policy forums, including the United Nations Framework Convention on Climate Change Conference of the Parties (COP) 17 and the first two conferences on Climate Change and Development for Africa, organised by partners in the Climate Development in Africa (ClimDev) programme.

Capacity building is a long-term and complex process which requires commitment and consistent interaction between partners. The capacity-building activities of the CSRP, based on consultation and mutual learning, are establishing a solid foundation for the future of strong climate science in Africa.

''The unique thing about the CSRP is the very good collaboration between the mentors and the Fellows, which creates a sense of belonging.''

Mrs Mary Kilavi, Kenya Meteorological Department and CSRP Fellow

Photo: Alfredo Caliz/Panos

''The best thing about being a CSRP Fellow is meeting other scientists, sharing ideas and opportunities that would best serve the interests of your country. The trump card is the network of relations that has been established.''

Dr Dominic Pokperlaar, Ghana Meteorological Agency and CSRP Fellow

The way forward

Lessons from the science outputs of the CSRP led directly to two recommendations in the outcomes statement of the first Climate Change and Development for Africa Conference in October 2011. They are an eloquent summary of what will be needed to build on the consultation, research and capacity-development activities of the CSRP in the future.

- African institutions and researchers, in collaboration with climate research and modelling partners, are called upon to strengthen their research programmes so as to improve the performance of global and regional climate models in representing African climate and its drivers.
- African institutions and researchers are called upon to identify and prioritise urgent scientific questions hindering practical action on adaptation so as to better understand and resolve inconsistencies between model projections and other research findings on likely rainfall trends across Africa.

''Our problem in developing countries is sustainability. The CSRP [has provided] efficient capacity building and a unique approach. Funding for a longer period would be great – a five-year partnership in a well-defined framework would be very helpful.''

Dr Ousmane Ndiaye, Senegalese Meteorological Service and CSRP Fellow

Photo: Sven Torfinn/Panos

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